Effects of Chemistry and Hydrology on Seed Germination and Plant Community Development in a Northern Everglades Wetland

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OBJECTIVE

This study investigated the relative importance of soil chemistry and hydrology as determinants of changes in plant community composition in response to canal-water intrusion into a historically rainfall-driven northern Everglades wetland.

INTRODUCTION

The A.R.M. Loxahatchee National Wildlife Refuge (Refuge) historically was an oligotrophic, rainfall-driven wetland with minimal nutrient and mineral inputs. Regional water management and land-use changes have altered the hydrology and chemistry of the Refuge in a manner similar to other parts of the Everglades. Canal waters entering the Refuge contain elevated concentrations of nutrients such as phosphorus (P) and minerals such as calcium (Ca) that can impact wetland vegetation. While the unique topography of the Refuge has limited canal-water intrusion into the Refuge interior, both the hydrology and soil chemistry around the perimeter of this wetland have been drastically altered by this intrusion.

Changes in vegetation communities within the Refuge have been attributed to human-induced alterations in hydrology and water quality. Species such as cattail (*Typha domingensis*) have displaced sawgrass (*Cladium jamaicense*) and slough habitats in canal-influenced areas around the Refuge perimeter (Richardson, 1990). Several other species such as *Xyris* spp. and some *Rhynchospora* spp. occur only in the Refuge interior (McCormick, 2007). We performed an experiment to measure the effects of hydrology and soil chemistry on plant-community development from the seed bank in order to understand the drivers of observed plant community distributions within the Refuge.

MATERIALS AND METHODS

Our experiment was conducted at the headquarters of the A.R.M. Loxahatchee National Wildlife Refuge in the northern Everglades (Figure 1). Soils were collected from the Refuge interior, cleaned of large roots and debris, and used to fill 24 plastic tubs (30 cm x 60 cm), which were maintained in a water bath (pools) and shielded from rainfall (Figures 2). Soils in half of the tubs were enriched by adding P and Ca to achieve concentrations similar to canal-impacted soils near the Refuge perimeter. Surficial soils were collected from several vegetative habitats across the interior and homogenized to obtain a diverse seed bank that was evenly distributed among the tubs. Four tubs of each chemistry treatment were subjected to one of three water-depth treatments (flooded, saturated, or drained). Enriched and unenriched tubs were hydrated with water from the L-40 canal and Refuge interior, respectively, until specific conductivity (µS/cm) exceeded predetermined levels (1000 and 200 µS/cm, respectively), after which time rainwater was used. Control tubs containing commercial potting soil were watered with canal water to confirm that this water was not a propagule source.

Figure 1. Map of Refuge (WCA-1) within remaining Everglades system.

Seedlings were tracked weekly with color-coded markers. Surviving seedlings were identified to species. Seedlings representing those that consistently died in non-enriched treatments were transplanted to separate containers of enriched soil and grown to an identifiable size. Percent abundances and biomass/plant were recorded for all treatments at the end of the nine-week experiment.

Differences in total germination, total survival, percent abundance, and biomass per plant were identified by MANOVA.

Figure 2. Outdoor experimental mesocosm at A.R.M. Loxahatchee National Wildlife Refuge.

RESULTS

The final water quality of treatments was representative of interior and perimeter conditions in the Refuge (Table 1). There was a total of 20 species present across all treatments (Table 2). Species such as *Xyris* spp. and *Utricularia* spp. failed to germinate in enriched treatments, while *Cyperus* spp., *Pluchea* spp., and *Ludwigia* spp. did not germinate in unenriched treatments. Other species such as *Mikania scandens* and *Typha domingensis* germinated in both treatments, but died off in the unenriched treatments during the course of the experiment.

Table 1. Water quality conditions of enriched and unenriched (control) treatments. Means, averages and minimums and maximums are presented for each enrichment treatment.

	Control			Enriched		
Variable	Mean	SE	Min-Max	Mean	SE	Min-Max
Specific Conductivity (µS/cm)	246.69	8.26	100-520	610.21	20.31	240-1110
Temperature (°C)	26.89	0.27	23.2-38.3	26.82	0.21	23.3-31.2
pH	5.97	0.04	5.71-6.18	6.82	0.02	6.7-6.91
Calcium (g/kg)	11	-	-	32	-	-
Phosphorus (mg/kg)	347	-	-	1460	-	-

Table 2. Species present in each enrichment and hydrology treatment.

	Nutrient Treatment Hydrology					
Plant Species	Control Dry	Control Flooded	Control Saturated	Impacted Dry	Impacted Flooded	Impacted Saturated
Rhynchospora inundata	X		X			
Rhynchospora tracyi	X	X	X			X
Rhynchospora. sppA	X	X	X	X	X	X
Rhynchospora sppB	X	X	X	X	X	X
Rhynchospora. sppX	X	X	X	X	X	X
Xyris spp.	X	X	X			X
Nymphaea spp.	X	X	X	X	X	X
Cyperus spp.				X		X
Typha domingensis	X	X	X	X	X	X
Utricularia spp.		X	X			
Ludwigia spp.				X	X	X
Pluchea spp.				X		X
Eleocharis spp.	X	X	X	X		X
Pontederia spp.					X	
Mikania scandens		X	X		X	X
Juncus megacephalus	X		X	X		X
Eriocaulon spp.	X					
Willow spp.				X		
Unknown Monocot	X	X	X	X	X	X
Unknown Dicot	X	X	X	X	X	X

Although many species were present in all treatments, enriched and unenriched treatments ultimately developed different communities as measured by percent abundances (Table 3 and Figure 3) and biomass per plant (Table 4 and Figure 4), with a visible difference in total biomass (Figure 5). There was greater overall germination in unenriched treatments ($p = <0.001$) but the total rate of survival was higher in enriched treatments ($p= 0.0062$). Hydrology treatments also yielded differences in abundance and biomass per plant for some species, independent of enrichment (e.g., *Rhynchospora* spp. (drained), *J. megacephalus* (flooded), although flooded treatments were confounded by noncompacted soils.

Table 3 . Results of MANOVA for the abundances (%) of each plant present.

Species	Enrichment	Hydrology	Enrichment* Hydrology
Rhynchospora spp.	0.0058	0.0004	0.2138
Xyris spp.	<0.0001	0.1762	0.4527
Nymphaea spp.	0.0322	0.907	0.2341
Cyperus spp.	0.0105	0.1391	0.1391
Typha domingensis	<0.0001	<0.0001	<0.0001
Utricularia spp.	<0.0001	<0.0001	<0.0001
Ludwigia spp.	0.0034	0.2797	0.2797
Pluchea spp.	0.079	0.3784	0.3784
Eleocharis spp.	0.5793	0.2084	0.0479
Pontederia spp.	0.3306	0.3874	0.3874
Mikania scandens	0.0431	0.1077	0.3254
Juncus megacephalus	0.0415	0.0118	0.2041
Eriocaulon spp.	0.0795	0.1794	0.1794
Salix caroliniana Michx.	0.1185	0.0953	0.0953
Unknown monocots	0.7095	0.4942	0.0632
Unknown dicots	0.6085	0.2219	0.0693
Dead seedlings	0.0026	0.177	0.1827

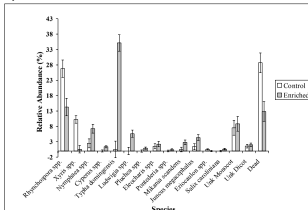

Figure 3. Abundances (%) for plants present in unenriched (control) and enriched treatments. Error bars represent standard errors.

Table 4. Results (p-values) of MANOVA for biomass per plant (mg) of species present Species occurring in both enriched and unenriched (control) treatments are marked with asterisks.

Species	Enrichment	Hydrology	Enrichment* Hydrology
*Rhynchospora spp.**	0.1018	0.2885	0.6442
*Xyris spp.**	0.0121	0.0033	0.0481
*Nymphaea spp.**	0.1764	0.4442	0.4439
Cyperus spp.	0.0043	0.0281	0.0281
*Typha domingensis**	<0.0001	<0.0001	<0.0001
Ludwigia spp.	0.0262	0.9023	0.9023
Pluchea spp.	0.0855	0.4404	0.4404
*Eleocharis spp.**	0.1280	0.1203	0.1147
Pontederia spp.	0.3306	0.3874	0.3874
*Mikania scandens**	0.1531	0.2991	0.5211
*Juncus megacephalus**	0.0781	0.0290	0.3266
*Eriocaulon spp.**	0.3306	0.3874	0.3874
Salix caroliniana Michx.	0.1744	0.1643	0.1643
Unknown monocots*	0.9706	0.2339	0.5082
Unknown dicots*	0.9696	0.1308	0.3478

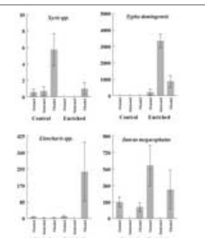

Figure 4. Biomass/plant (mg) for select species present in both enriched and unenriched (control) treatments. Error bars represent standard deviations.

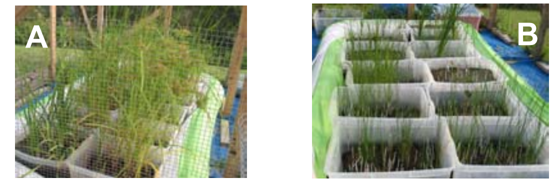

Figure 5. Final plant communities of nutrient enrichment (enriched and unenriched) and hydrology (drained, saturated, and flooded) treatments. Enriched treatments are presented in the left panel (A) and unenriched treatments are pictured in the right panel (B). Hydrology treatments were randomly dispersed among tubs for each enrichment treatment.

Weekly seedling survival was different for two species (*Rhynchospora* spp. and *Xyris* spp.) that were present in both enriched and unenriched treatments but were significantly more abundant in unenriched treatments (Figure 6). *Xyris* spp. also had significantly greater biomass per plant in unenriched treatments (Figure 4). These species, which are primarily found in the Refuge interior, were far more common and robust in unenriched (control) treatments (Figure 3).

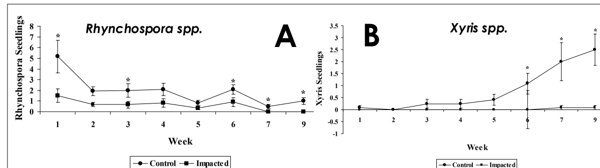

Figure 6. Weekly germination of *Rhynchospora spp.* seedlings (left panel; A) and *Xyris spp.* seedlings (right panel; B). Error bars represent standard deviations. Points marked with asterisks are significantly different (95% confidence).

ECOSYSTEM RESTORATION IMPLICATIONS

While hydrologic treatments had some influence on species composition, the chemistry treatments produced distinct plant communities indicative of the Refuge interior (unenriched treatment) and perimeter (enriched treatment). Results suggest that seedling germination and survival are major drivers of plant communities that develop in the Refuge. Because soil chemistry significantly impacts seedling dynamics, wild communities can be impacted in a single season, particularly in drought conditions when these parameters would be dominant factors responsible for community recruitment.

Our findings have important implications for efforts to restore and maintain native Everglades plant communities. Specifically, our results show that:

- While hydrology certainly is a critical factor affecting Everglades vegetation, soil and surface-water chemistry can exert strong independent effects on plant communities;
- Soil chemistry is a major determinant of differences in plant communities between the minimally impacted Refuge interior and enriched areas near the perimeter;
- Effects of soil chemistry on plant community development can occur within a single growing season after disturbances such as droughts, when vegetative cover is reduced and plant establishment from the seed bank may be important.

REFERENCES

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